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M.A. Moinester et al.

The SELEX/E781 Collaboration

*Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510*

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INELASTIC ELECTRON-PION SCATTERING at FNAL (SELEX)

The SELEX Collaboration

M.A. Moinester¹², A. Ocherashvili¹², V. Steiner¹², N. Akchurin¹⁶,
V.A. Andreev¹¹, A.G. Atamantchouk¹¹, M. Aykac¹⁶, M.Y. Balatz⁸,
N.F. Bondar¹¹, A. Bravar²⁰, P.S. Cooper⁵, L.J. Dauwe¹⁷, G.V. Davidenko⁸,
U. Dersch⁹, A.G. Dolgolenko⁸, D. Dreossi²⁰, G.B. Dzyubenko⁸,
R. Edelstein³, L. Emediato¹⁹, A.M.F. Endler⁴, J. Engelfried^{5,13},
I. Eschrich^{9,a}, C. Escobar^{19,b}, A.V. Evdokimov⁸, I.S. Filimonov^{10,c},
F.G. Garcia¹⁹, M. Gaspero¹⁸, S. Gerzon¹², I. Giller¹², V.L. Golovtsov¹¹,
Y.M. Goncharenko⁶, E. Gottschalk^{3,5}, P. Gouffon¹⁹, O.A. Grachov^{6,d},
E. Gülmez², He Kangling⁷, M. Iori¹⁸, S.Y. Jun³, A.D. Kamenskii⁸,
M. Kaya¹⁶, J. Kilmer⁵, V.T. Kim¹¹, L.M. Kochenda¹¹, K. Königsmann^{9,e},
I. Konorov^{9,f}, A.P. Kozhevnikov⁶, A.G. Krivshich¹¹, H. Krüger⁹,
M.A. Kubantsev⁸, V.P. Kubarovsky⁶, A.I. Kulyavtsev^{6,3},
N.P. Kuropatkin¹¹, V.F. Kurshetsov⁶, A. Kushnirenko³, S. Kwan⁵, J. Lach⁵,
A. Lamberto²⁰, L.G. Landsberg⁶, I. Larin⁸, E.M. Leikin¹⁰, Li Yunshan⁷,
Li Zhigang⁷, M. Luksys¹⁴, T. Lungov^{19,g}, D. Magarrel¹⁶, V.P. Maleev¹¹,
D. Mao^{3,h}, Mao Chensheng⁷, Mao Zhenlin⁷, S. Masciocchi^{9,i}, P. Mathew^{3,j},
M. Mattson³, V. Matveev⁸, E. McCliment¹⁶, S.L. McKenna¹⁵,
V.V. Molchanov⁶, A. Morelos¹³, V.A. Mukhin⁶, K.D. Nelson¹⁶,
A.V. Nemitkin¹⁰, P.V. Neouistroev¹¹, C. Newsom¹⁶, A.P. Nilov⁸,
S.B. Nurushev⁶, G. Oleynik^{5,h}, Y. Onel¹⁶, E. Ozel¹⁶, S. Ozkorucuklu¹⁶,
S. Patrichev¹¹, A. Penzo²⁰, P. Pogodin¹⁶, B. Povh⁹, M. Procario³,
V.A. Prutskoi⁸, E. Ramberg⁵, G.F. Rapazzo²⁰, B.V. Razmyslovich¹¹,
V.I. Rud¹⁰, J. Russ³, P. Schiavon²⁰, V.K. Semyatchkin⁸, J. Simon⁹,
A.I. Sitnikov⁸, D. Skow⁵, V.J. Smith¹⁵, M. Srivastava¹⁹, V. Stepanov¹¹,

^aNow at Imperial College, London SW7 2BZ, U.K.

^bCurrent Address: Instituto de Fisica da Universidade Estadual de Campinas, UNICAMP, SP, Brazil

^cdeceased

^dPresent address: Dept. of Physics, Wayne State University, Detroit, MI 48201

^eNow at Universität Freiburg, 79104 Freiburg, Germany

^fNow at Physik-Department, Technische Universität München, 85748 Garching, Germany

^gCurrent Address: Instituto de Fisica Teorica da Universidade Estadual Paulista, São Paulo, Brazil

^hPresent address: Lucent Technologies, Naperville, IL

ⁱNow at Max-Planck-Institut für Physik, München, Germany

^jPresent address: Motorola Inc., Schaumburg, IL

- L. Stutte⁵, M. Svoiski¹¹, N.K. Terentyev^{11,3}, G.P. Thomas¹, L.N. Uvarov¹¹,
A.N. Vasiliev⁶, D.V. Vavilov⁶, V.S. Verebryusov⁸, V.A. Victorov⁶,
V.E. Vishnyakov⁸, A.A. Vorobyov¹¹, K. Vorwalter^{9,k}, J. You³,
Zhao Wenheng⁷, Zheng Shuchen⁷, R. Zukanovich-Funchal¹⁹
¹Ball State University, Muncie, IN 47306, U.S.A.
²Bogazici University, Bebek 80815 Istanbul, Turkey
³Carnegie-Mellon University, Pittsburgh, PA 15213, U.S.A.
⁴Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, Brazil
⁵Fermilab, Batavia, IL 60510, U.S.A.
⁶Institute for High Energy Physics, Protvino, Russia
⁷Institute of High Energy Physics, Beijing, P.R. China
⁸Institute of Theoretical and Experimental Physics, Moscow, Russia
⁹Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany
¹⁰Moscow State University, Moscow, Russia
¹¹Petersburg Nuclear Physics Institute, St. Petersburg, Russia
¹²Tel Aviv University, 69978 Ramat Aviv, Israel
¹³Universidad Autónoma de San Luis Potosí, San Luis Potosí, Mexico
¹⁴Universidade Federal da Paraíba, Paraíba, Brazil
¹⁵University of Bristol, Bristol BS8 1TL, United Kingdom
¹⁶University of Iowa, Iowa City, IA 52242, U.S.A.
¹⁷University of Michigan-Flint, Flint, MI 48502, U.S.A.
¹⁸University of Rome “La Sapienza” and INFN, Rome, Italy
¹⁹University of São Paulo, São Paulo, Brazil
²⁰University of Trieste and INFN, Trieste, Italy

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We describe the analysis status of SELEX electron-pion inelastic $\pi e \rightarrow \pi' e' \gamma$ and $\pi e \rightarrow \pi' e' \pi^0$ reaction data.

1 Introduction

The SELEX experiment (E781) at Fermilab ¹ focused on charm hadroproduction ² at large X_F , using 590 GeV/c π^- and Σ^- and proton beams. We took data simultaneously with the same beams and electron targets (atomic electrons in nuclear target) for elastic ³ and inelastic hadron-electron scattering. Here, we describe the analysis status of electron-pion inelastic scattering $\pi e \rightarrow \pi' e' \gamma$ and $\pi e \rightarrow \pi' e' \pi^0$ reaction data. We will discuss these reactions in

^kPresent address: Deutsche Bank AG, 65760 Eschborn, Germany

terms of the kinematic variables defined in Fig. 1a. The data give information on reactions that were never previously measured: (1) $\pi e \rightarrow \rho e'$ scattering for a determination of the $\rho \rightarrow \pi\gamma$ radiative width from a measurement of the transition form factor (FF) near zero momentum transfer; (2) $\pi e \rightarrow e'\pi'\pi^0$ scattering near threshold for a determination of the chiral anomaly transition FF and the $\gamma \rightarrow 3\pi$ $F_{3\pi}$ chiral anomaly amplitude; and (3) $\pi e \rightarrow \pi'e'\gamma$ scattering, in which a virtual photon from the electron's Coulomb field is Compton scattered on the pion, for a determination of the never previously measured generalized pion polarizabilities.

2 The SELEX Setup

The SELEX three-stage magnetic spectrometer allowed us to measure the complete kinematics of the reaction. Scattering angles and momenta of both the hadron and the electron were measured with high precision using silicon microstrip detectors located before and after the targets, and at small angles after the SELEX magnets. There are also proportional wire and drift chambers for measuring charged tracks. The tracking planes are organized in spectrometers, interspaced with dipole magnets for momentum analysis. There are three lead glass calorimeters for photon detection and electron identification after each magnet. There is a transition radiation detector (TRD) that tags the type of beam particle, and a second TRD after the second magnet for electron identification. There is a ring imaging Cherenkov counter (RICH) for particle identification. For the trigger, we use an ensemble of fast scintillation detectors for beam definition, two scintillation interaction counters which measure an energy loss appropriate to two final state charged particles, and a scintillation hodoscope downstream after the SELEX magnets to also identify two negative charged particles.

3 Physics Topics

3.1 Excitation of the ρ

Data analysis is in progress for the reaction $\pi e \rightarrow e'\pi'\pi^0$, to identify the $\pi e \rightarrow \rho e'$ channel. Such data will allow a determination of the $\rho \rightarrow \pi\gamma$ radiative width from a measure of the transition FF (near zero momentum transfer). For this study, the two detected γ 's must have a π^0 invariant mass, and the $\pi\pi^0$ system must have the invariant mass of the ρ .

The π^- has $J^\pi = 0^-$ and the ρ^- has $J^\pi = 1^-$. A spin-flip M1 transition is required. The transition FF is given (schematically) by the overlap integral:

$F(q^2) = \int \Psi[\rho(\vec{r})]^* \Psi[\pi(\vec{r})] \exp(i\vec{q}\vec{r}) [\sigma Y 1(\vec{r})] d\vec{r}$, where $\Psi[\rho(\vec{r})]$ and $\Psi[\pi(\vec{r})]$ are ρ and π wave functions, σ is the spin flip operator, and \vec{q} is the momentum transfer. The FF probes our understanding of the pion and rho wave functions^{4,5}. The ρ radiative width ($\Gamma(\rho \rightarrow \pi\gamma \approx 70 \text{ KeV})$) is fixed by the value of the FF at $q^2 = 0$. There is a known relationship of the radiative width to the FF⁵. Our studies of the ρ channel will be also valuable for understanding the chiral anomaly reaction $\pi e \rightarrow e' \pi' \pi^0$.

3.2 Chiral Anomaly Transition

For the γ - π interaction, the $O(p^4)$ chiral lagrangian includes Wess-Zumino-Witten (WZW) terms^{6,7,8}, which lead to an abnormal intrinsic parity (chiral anomaly) term in the divergence equations of the currents. Data for $e\pi \rightarrow e' \pi' \pi^0$, where the $\pi\pi^0$ system has invariant mass lower than the ρ , near threshold, should determine the chiral anomaly transition FF $\pi\gamma \rightarrow \pi' \pi^0$, and $\gamma \rightarrow 3\pi$ $F_{3\pi}$ amplitude at threshold. The $O(p^4)$ prediction^{6,7} is $F_{3\pi} = 9.7 \text{ GeV}^{-3}$. Holstein⁶ gives the transition FF as $F = F_{3\pi} \times f$, where f is a known function of the kinematic variables. The absolute cross section data for $\pi e \rightarrow e' \pi' \pi^0$ should determine $F_{3\pi}^2$, and the kinematic dependence should determine the shape f^2 .

Antipov et al.⁹ measured $F_{3\pi}$ with 40 GeV pions. Their study involved pion production by a pion in the nuclear Coulomb field via the Primakoff reaction: $\pi^- Z \rightarrow \pi'^- \pi^0 Z'$. The Antipov et al.⁹ experiment (with roughly 200 events) yielded $F_{3\pi} = 12.9 \pm 0.9(stat) \pm 0.5(sys) \text{ GeV}^{-3}$. A reanalysis by Holstein⁶ gave $F_{3\pi}$ lower by 1 GeV^{-3} . Bijmens et al.⁸ studied higher order χ PT corrections. For $F_{3\pi}$, they increase the theoretical prediction by around 1 GeV^{-3} . The prediction at $O(p^6)$ is then $F_{3\pi} \sim 10.7$, closer to the data. The limited accuracy of the existing data, together with the new calculations of Bijmens et al., motivate an improved and more precise experiment.

3.3 Pion Generalized Polarizabilities

The virtual Compton scattering (VCS) reaction $\pi e \rightarrow \pi' e' \gamma$ is sensitive to the generalized pion electric and magnetic polarizabilities $\bar{\alpha}_\pi(q)$ and $\bar{\beta}_\pi(q)$, which depend on momentum transfer (q) to the electron^{10,11}. At zero momentum transfer, these reduce to the usual Compton polarizabilities¹². The VCS process and planned proton VCS experiments at electron accelerators have been discussed extensively¹³. S. Scherer et al.¹⁴ are calculating pion VCS.

For pion VCS, the Bethe-Heitler (BH) amplitude (γ from electron) dominates over the Compton (C) amplitude. But the Compton amplitude should be relatively more enhanced compared to BH for events in which the angle

between γ and electron is large. The complete transition amplitude is BH+C, with the BH amplitude much larger than the C amplitude. The cross section depends on $BH^2 \pm 2 (BH) (C) + C^2$, where the sign changes between positive and negative pion beams¹⁴. We will compare our π^- VCS data to the theoretical calculations, by incorporating the theory into the SELEX GEANT simulation package¹⁵. The object is to fit the data to obtain the generalized polarizabilities with their momentum transfer dependences, and also the $q=0$ Compton limit.

4 Data Analysis Status

4.1 Excitation of the ρ

In Fig. 1b, we show a reconstruction of the $\pi + 2\gamma$ invariant mass, when the $\gamma\gamma$ invariant mass is around the π^0 mass. Only events with two detected γ -rays above 1 GeV were considered. Fig. 1b is a raw analysis spectrum, not with the final analysis package, not with all possible kinematic cuts, and not acceptance corrected. Such is the case also for other preliminary spectra shown in this paper. But we can already clearly see signs of a ρ resonance peak close to the expected mass. Data analysis methods are being improved, and should reduce backgrounds. With lower backgrounds and acceptance corrections, we may look at the lower mass chiral anomaly region. We will again compare theory and data with the help of the SELEX GEANT package¹⁵. The yield falls with q^2 , as shown in Fig. 1c.

4.2 Generalized Polarizabilities

In $\pi e \rightarrow \pi \gamma e$, a virtual photon from the electron's Coulomb field is Compton scattered on the pion. Preliminary data from the 1- γ channel are shown in Fig. 1d, for events with only one detected γ -ray above 1 GeV. The data are due to 1- γ physics events, and part is due to "1- γ " background from the $\pi e \rightarrow \pi \pi^0 e$ channels for events in which one γ from the π^0 decay does not satisfy all our detection criteria. We are making first estimates of this background by taking our $\pi e \rightarrow \rho e'$ production rate, building an event generator for this process, and using the SELEX GEANT simulation package. Our aim is to subtract the estimated background from the measured 1- γ spectra. Our simulation work is in progress, so that the resulting background subtracted spectra are not yet available. The S_1 dependence of the data is shown in Fig. 1d. The data peaks at the lowest S_1 bin, as expected for the Bethe-Heitler process.

5 Conclusions

We describe first electron-pion inelastic data via the SELEX experiment. We do not give any final results for the pion-electron inelastic channels. Our aim here is rather to show work in progress, and to help generate needed theoretical support.

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1. Ball State University, Bogazici University Istanbul, Carnegie Mellon University, Centro Brasileiro de Pesquisas Fisicas Rio de Janeiro, Fermilab, IHEP Beijing, IHEP Protvino, ITEP Moscow, Max Planck Institute for Nuclear Physics Heidelberg, Moscow State University, Petersburg Nuclear Physics Institute, Tel Aviv University, Universidad Autonoma de San Luis Potosi, Universidade Federal da Paraiba, University of Bristol, University of Hawaii, University of Iowa, University of Michigan-Flint, University of Rochester, University of Rome 'La Sapienza' and INFN Rome, University of São Paulo, University of Trieste and INFN Trieste.
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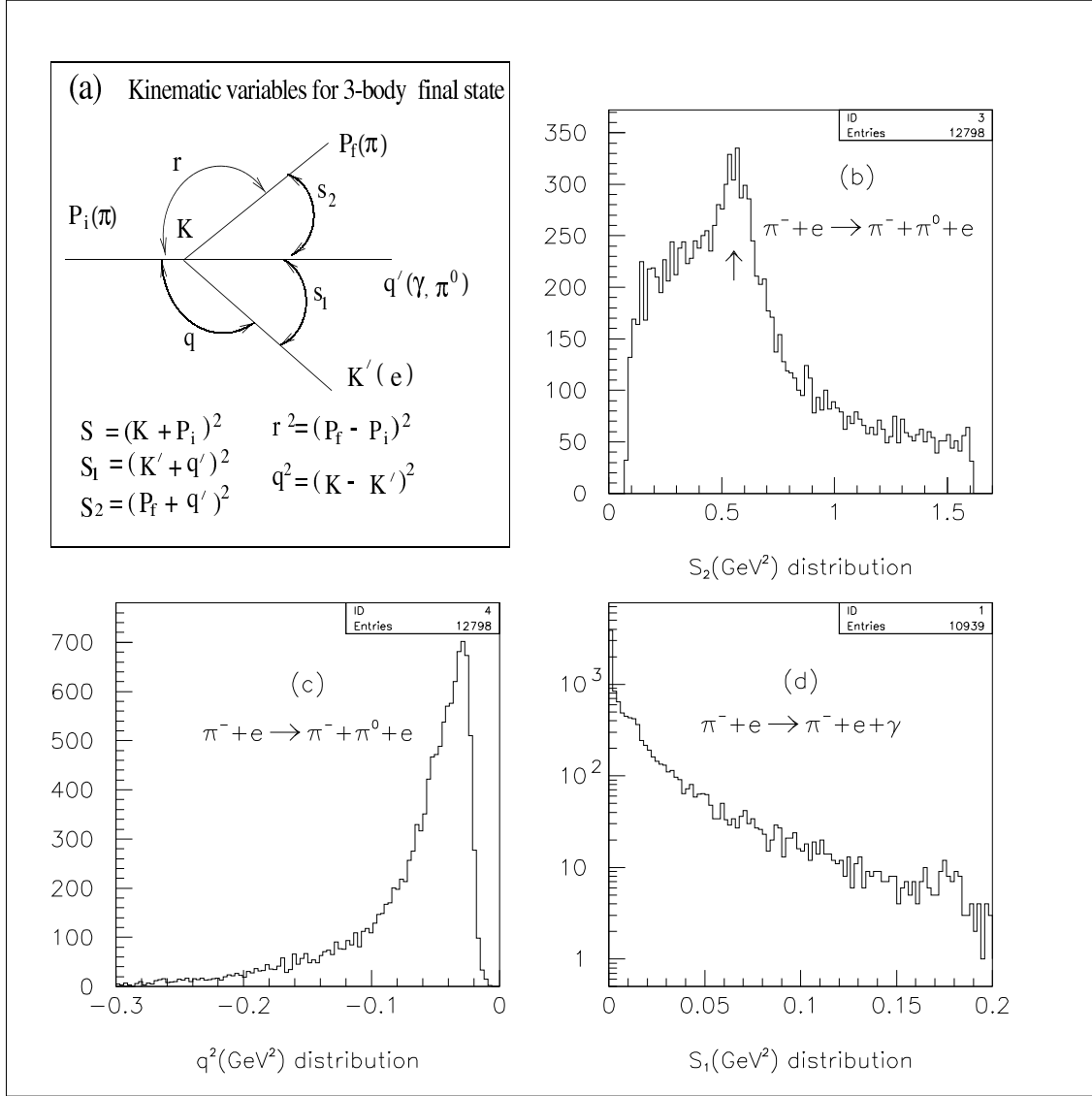


Figure 1. (a) Kinematic variables for reaction $\pi^- + e \rightarrow \pi^- + e + \gamma$ and $\pi^- + e \rightarrow \pi^- + e + \pi^0$. P_i is the 4-momentum of the incoming π^- beam, K is the 4-momentum of the *electron* target, P_f is the 4-momentum of the outgoing π^- , q' of the outgoing γ in case of $\pi^- + e \rightarrow \pi^- + e + \gamma$ or π^0 in case of $\pi^- + e \rightarrow \pi^- + e + \pi^0$, K' is the 4-momentum of the outgoing *electron*. SELEX preliminary data (b, c): Distributions of events versus S_2 and q^2 for the reaction $\pi^- + e \rightarrow \pi^- + e + \pi^0$. The arrow in (b) gives the expected position of the ρ . SELEX preliminary data (d): Distributions of events versus S_1 for the reaction $\pi^- + e \rightarrow \pi^- + e + \gamma$.